Ultra-High Resolution Imaging of Energetic Material Modifiers

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MEETING ANNOUNCEMENT & CALL FOR PAPERS

31st Propellant Development & Characterization Subcommittee (PDCS)
20th Safety & Environmental Protection Subcommittee (SEPS)
Joint Meeting
March 24-27, 2003 – Charlottesville, Virginia

ABSTRACT

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Development of novel energetic with improved performance, sensitivity and vulnerability properties require many years between conception, synthesis, scale-up, formulation & processing, and evaluation. Recent approaches have focused on using modifiers, which might be added at relatively low levels for improving the properties of existing propellant and explosive formulations, or alternatively, modify existing energetic materials themselves for improved properties. Research in nanotechnology, aided by advancements in instrumentation for imaging and characterization at the nano-scale, has become an important focus for modification of materials in general. Nanomaterials also offer potential for energetic materials, for improving ignition, burning and combustion, and response to initiation phenomena, but exploitation of these materials requires an understanding of their detailed structure which gives them special functional characteristics that make them attractive for materials modification.

In this paper, nanoscale imaging, and even sub-nanoscale imaging approaching atomic dimensions has been performed on energetic materials of interest for both explosive and propellant modification. Nano-scale modification of propellants with extended structures such as carbon nanotubes is of interest for tailoring the burning rate of propellants for co-layered charge designs which require a nominal burning rate differential of a factor of 3 in order for performance gains to be realized. However, nanotube structures can vary significantly in length, diameter, or whether they are curly or straight, multi-and single-wall, depending on synthesis parameters, so that correlation with performance results requires quality control of the nanotubes being used. In using nanotubes in polymers for commercial application, it was found that achieving uniform dispersion can be problematic due to the lack of affinity of the carbon structure for polar functional groups. An approach to improve dispersion is to modify the carbon structures with oligimers containing functional groups that will associate with those of the polymer of interest, and which will facilitate incorporation of the nanotube, much the way surfactants are used to bridge polar and non-polar species. Functionalization of carbon nanotubes is being pursued at ARL, and the high resolution imaging of nanotubes that have been functionalized with several different polymers has been performed. The results will be presented in this paper.

Aluminum oxide is of great interest for explosives applications, and especially recently, nano-aluminium is a major focus of research for thermobaric applications. Mechanisms controlling the effectiveness of nano-aluminum in modifying explosive properties are not well understood, but it is becoming increasingly clear that the particular structural characteristics of the nano-aluminum are key to understanding and controlling not only its performance but sensitivity and vulnerability properties as well. The properties of the oxide passivation coating, including chemical structure and purity, thickness, and physical & crystallographic structure are important to analyze, understand and control. Ultra-high resolution electron microscope images of the nano-aluminum structure will be presented, and possible implications of this structure for explosive properties will be discussed.